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Influence of Soil Textural Properties and Land Use Cover Type on Soil Erosion of a Characteristic Ultisols in Betem, Cross River Sate, Nigeria

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Abstract

This study on the influence of soil textual properties and land use cover type on soil erosion of a characteristics ultisols. Betem, Cross River State, Nigeria was conducted with the aim of determining the relationship between land use type and soil loss in the context of a characteristics ultisols. Soil samples were manually collected from the respective land use types with the aid of soil auger at the depth of 0-15cm for the laboratory analysis of particle size distribution while data on sediment yield deposit were obtained through the use of sediment traps or dishes placed at the foot of the respective slopes. The result of the textural characteristics revealed that particle size distribution showed large proportion of sand. Thus, sand ranged from 72-78% with a mean of 75.0%, silt ranged from 11-12% with a mean of 11.0% while clay ranged from 12.0% - 16% with a mean of 14.0%. The result showed that sand was the dominant particle fraction and any soil that is characterized by huge sand proportion can be vulnerable to erosion perturbation. The various land cover types have revealed their potentials in reducing erosion perturbation. The result of sediment yield obtained under these land use types revealed the following ranges and means: bare land surface ranged from 40-360g with a mean of 182.2g, cassava plot, ranged from 30-238 with a mean of 107.6g, bush fallow ranged from 4-150g with a mean of 30.0g; secondary forest plot ranged from 2-48 with a mean of 15.0 grams while primary forest plot has a range of 1-45 with a mean of 13.4g respectively. The study revealed that it is the unguided use of land that exposes soils to the direct effect of weather elements hence the major cause of soil erosion in the area. The study, therefore suggests an appropriate land or soil management system that can guarantee adequate protection of soil and other variable components of the environment.

Keywords: land use cover, soil erosion, soil textural characteristics

1. Introduction

Erosion of soil by wind or water has some important impact on the overall sustainability of various components of the environment; perhaps, the main source of most ecological disaster, particularly in the tropical and semi-arid regions of the world. Soil, slope gradient, rainfall and land cover type can combine (or in isolation) to cause soil loss through water erosion in the tropics, especially in the face of obvious alteration of the original landscape. Scherr (1995) identifies land use change as consequences of human activities. He pointed out that a huge proportion of natural landscape has been altered adversely owing to human activities. The effect of these activities is the main cause of the frequent ecological problems.

In Nigeria, studies have shown that human activities are the main cause of soil erosion (Olatunji, 2002; Madu, 2004; Lorkua & Ikyernum, 2004). This is because they contribute significantly to the alteration of land use a situation that predisposes soils to the vagaries of nature. Several authors have reported that land use and topography have great influence on soil erosion (Carda et al., 1995; Imeson et al., 1998; Seeger & Ries, 2008). Studies have equally shown that soil physical parameters, particularly, textures can be used in determining soil susceptibility to erosion perturbation (cammeraat & Imeson, 1998), surface characteristics can as well be used for the said purpose (Mackel & Walter, 1911).

The impact of erosion are enormous, they include the lowering of soil production capacity (Bou Kheir, 2008) hence, the main cause of low crop yield, a situation that requires higher input to bring the land back to shape (Quinton & Catt, 2004). Others include sediment yield in streams and reservoirs, reduction of water quality status and the deposition of toxic materials on farmland (Poesen & Hook, 1997).

In Cross River State, Nigeria where Betem belongs, over 802 gully erosion sites were identified in 1992 by the United Nation Development Programe (UNEP). This accounted for the lost of farm lands, flooding, water pollution and the destructions of buildings and social amenities (Nigerian Environmental Study Team [NEST], 1999). Betem lies in the tropics where there is a widespread effect of rainfall intensity coupled with the attendant long duration and frequency, these factors are indeed the main driving forces of the huge loss of soil material in the area. Hence, creating erosion scarps and gullies (Morgan, 1981; Roose, 1967) necessitating shrinkage and the eventual disappearance of streams. Others include, the implication on agricultural productivity and the lost of biodiversity. Against the backdrop of the growing need to achieve a sustainable environment, it therefore becomes a matter of critical importance to assess the textual characteristics of soils across the various land use types. Hence, the relationship with sediment deposition and the consequent soil lost perturbation in the area. The study hypothesis was that sediment yield cannot be influenced by land use type while the objective was to find the relationship between soil loss and land use type in the area. An understanding of this will help in the protection of soils as well as assist in harnessing the variable landscape potentials in overall sustainability process.

2. Study Area

The study location is Betem, which lies between Latitudes 5°30′ and 5°35′ N and Longitudes 8°06′ and 8°11′ E in Cross River State, Nigeria. The relief is predominantly gentle slope with an elevation of not less than 150m above sea level. The soil is composed of Ultisols (Egbai, 2011). The soil type suggests an environment where agricultural activity can thrive effectively. The secondary forest is capable of trapping and retaining rain water which invariably helps in ground water recharge (Eze & Abua, 2002). The area falls under the humid tropical rainfall zone and experiences a mean annual rainfall of between 2000-3500mm (CRADP, 1992). The soil moisture and temperature regimes are Udic and Isohyperthermic.

2.1 Materials and Method

Six sites were arbitrarily selected to reflect the dominant land use types. They consist of bare land, cassava farm land and palm plantation amongst other land use types in the area. Sloppy terrains were preferred because steepness of slope determines fluvial flow to a very large extent. Steep slope encourages accelerated erosion, reduces the amount of water percolating through the soil and decrease the upper portion of the soil profile resulting in a relatively shallow and poorly differentiated soil profile (Sehgal, 1986; Ogunkunle & Onasanya, 1992; Ibanga, 2003; Adekoyade, 2007).

In each of these land use environment, soil samples were collected for laboratory analysis with the aid of soil auger at a layer of 0-15cm for the determination of its textural characteristic. Soil samples were collected, air dried and sieved through a 2mm mesh into a well labeled polythene bag. The samples were subjected to laboratory analysis to determine the particle size distribution by Bouyoucos hydrometer method (Bouyoucos, 1926; Gee & Bounder, 1986).

Sediment traps of 60m x 90m x 60m were placed at the foot of the slope in each of the land use types. These traps were designed in such a way as to allow water that flows with the particulate sediment into the trap to drain out leaving only the sediment in the trap. Sediment yield from each land use plot were exhumed and weighed with an appropriate weighing balance to determine the quantity of sediment from the respective plots. The total soil loss during each storm event was computed as the product of sediment concentration or yield in gram (g).

3. Result and Discussion

In Table 2, sand is the dominant particle size fraction. Because sand lacks cohesion, sand sharing was facilitated. Soils that are predominantly sandy tend to be highly erosive because of ease of detachment and transport of particles. The region has a monolithologic sedimentary characteristic. Apparently from the result in Table 2, it could be stated that there was no clear difference in the soils of the various land use types. Kowal and Thinker (1959), Omoti et al. (1986) and Aweto (1987) had earlier obtained similar results. However, there is a clear relationship between soil loss and the land use type in the study area. This implies that the volume of soil that is lost to erosion during rain storm event is not only a function of slope, rainfall intensity or duration but a function of land cover condition. From the Table, bare surface produced the highest volume of sediment yield of 3157g with substantial quantity of sand of 78% and the list quantity of 10% clay and 12% silt respectively. This is because the surface was exposed to the direct impact of weather elements. Meanwhile, the least amount of sediment yield of 226g was recorded in forested land with the lowest value of sand and considerable high values of 16% clay and 12% silt respectively. The differences in the values of sediment yield from the various land use types reflect the density of vegetal cover in the study area. This is because plants/crops offer coverage to the soil surface thus, protecting it from the direct impact of raindrop *vis a vis* influence of fluvial action.

The soils of the area have homogenous textural characteristics. For example, soil from different land use fell between the range of 72-78% for sand, 11-12% silt and 12-16% clay and a mean value of 75.0% of sand, 11.0% silt and 14.0% clay respectively. The sandy texture of the soils is a reflection of the high quartz content and the coarse textured nature of rocks of the area (Essoka, 2008; Ekpe, 2002; Okon, 2002; Onula, 2003). Hence, the soil particulate matter is a direct fall out of precipitating material from the said rocks.

The values of slope dimension are presented in Table 1. The percent slope for the sample plots range between 5.8 - 6.3% and mean of 5.6%). According to Monkhunse (1971) potential soil loss on land more than 2% slope can exceed the tolerable soil loss. Therefore, the affected area is obviously impacted by erosion process. Thus, with the average slope of approximately 6% in the referenced area it implies that the potential soil loss due to runoff will be high if ground cover is removed or if forest is lost. The slope or topographic characteristic and its length can combine to influence the extent of erosion or soil loss. Though, this is largely dependent on the soil and land cover types. Implying that, the soil texture determines the extent of detachability and transportation of soil materials, hence, giving credence to a phenomenon of massive reduction of nutrient, sedimentation and water pollution scenarios.

Table 1.The key attributes of the experimental plot in the watershed

Plot/SN	Land type	Bearing	Latitude	Longitude	Slope	Height	Directional information
Plot 1-A	Bare Land Surface (BL)	137°	008°09'05"N	008°09'24"E	5.9%	382m	North East
Plot 1-B	Cassava Farm Plot (CP)	172°	005°28'35"N	008°09'24"E	6.1%	373m	North East
Plot 1-C	Fallow Bush (FB)	173°	005°28'31"N	008°08'16"E	5.9%	355m	North East
Plot 1-D	Primary Forested Land (PFL)	172°	005°28'16"N	008°08'24"E	6.2%	389m	North East
Plot 1-E	Maintained Palm plot (MPP)	167°	005°31'44"N	008°09'29"E	5.8%	379m	North East
Plot 1-F	Secondary forest land (SFL)	171°	005°31'36"N	008°08'4"E	6.3%	390m	North East

Source: Researcher's Field Work, 2010.

Table 2. Soil composition of land use types in Betem Region

	Plot	Slope %	Sand %	Silt %	Clay %	Texture
1	Bare	5.9	78.0	10.0	12	SL
2	Cassava	6.1	77.0	11.0	12.0	SL
3	Fallow Bush	5.9	76.0	11.0	12.0	SL
4	Maintained Palm	5.8	75.0	11.0	14.0	SL
5	Secondary forest	6.3	74.0	11.0	15.0	SL
6	primary Forest land	6.2	72.0	12.0	16.0	SL
	Range	5.3-6.3	72-78	11-12	12.6	
	Mean	6.0	75.0	11.0	14.0	

Source: Researcher's field work (2010)

The rainfall data obtained at the 17days of rainfall are shown in Table 3, ranged between 25-66.5 mm while the mean value was 47mm. Rainfall especially the amount, intensity, duration and distribution affect erosion to the extent that they influence the kinetic stress of the rain storm. It has been estimated that <25mm/hr of rainfall intensity will be non-erosive, 40% of rains in the tropics were Betem belongs are erosive and could go as high as 150mm/hr (Ibanga, 2002).

The land use types are shown in Table 3 they include bare land surface, cassava plot, bush fallow plot, oil palm plot, secondary forest land area and primary forest plot, respectively. The result of sediment yield obtained under these land use types revealed the following ranges and means: bare land surface ranged from 40-360g with a mean of 182.2g, cassava plot, ranged from 30-238 with mean of 107.6g, bush fallow ranged from 4-150g with a mean of 30.0g; secondary forest plot ranged from 2-48 with a mean of 15.0 grams while primary forest plot has a range of 1-45 with a mean of 13.4g respectively.

Table 3. Shows the amount and quantity of rainfall and the corresponding sediments yields in grams in respective land use types

S/N	Rainfall (MM)	Bare Band	Cassava Plot	Bush Fallow	Oil Palm Land	Secondary Forest Land	Primary Forest Land
1.	66.5	345	235	150	82	48	45
2.	49.2	205	120	120	50	25	15
3.	38.2	110	87	50	28	10	5
4.	45.8	185	95	50	25	13	5
5.	66.1	360	238	100	70	40	32
6.	62.1	346	220	115	71	28	25
7.	35.5	60	30	5	5	5	5
8.	41.3	115	50	10	7	5	5
9.	44.0	52	32	5	3	2	5
10.	40.1	112	48	10	5	2	5
11.	60.2	328	200	89	45	25	28
12.	45.0	170	84	50	28	18	10
13.	40.6	101	40	8	5	2	3
14	38.0	98	50	25	10	5	2
15	62.0	358	225	101	68	20	30
16.	25.1	40	30	4	3	3	1
17.	40.25	112	40	9	4	3	5
Range	25.1-66.5	40-360	30-238	4-150	3-82	2-48	1-45
Mean	44.7	182.2	107.6	30.0	30.1	15.0	13.4

Source: The researcher's field work (2010).

The result reveals that the ratio of sediment yield of 1:40 was recorded between the bare land and the primary forest plots. Meaning that rainfall amount of 25.1mm can generate sediment yield on a bare land surface which can be 40 times more than what is generated in protected land area with vegetation. The amount or quantity of sediment deposit as reflected in the various land use types indirectly indicates the level of runoff from these land cover types. Thus, the volume of sediment deposit or yields from the bare land to the primary forest represents the density of vegetal cover in the respective plots. Sediment yield or runoff decreases progressively from bare land surface to primary forest land use type.

The study reveals that runoff is a major cause of erosion because it is the agent that provides the energy for detachment and transportation of soil particles and their eventual deposition at the slope bottom. Thus, the decrease in sediment deposit from bare surface to the primary forest area was as a result of progressive increases of vegetative cover from bare surface to primary forest area. Therefore, the main cause of increased sedimentation and consequently, the extent of erosion is the removal of vegetation. From this study it has been revealed that the factors determining the extent and intensity of soil erosion by water include soil types, slope, and land cover type and rainfall intensity.

Soil type poses tremendous influence on soil erosion while the properties of soil that aid in easy detachment of soil particles are particle size distribution (texture), structure, organic matter content, content of polyvalent metals and permeability. Slope factors that determine extent of erosion are length of slope, slope type (convex, concave or regular) and slope steepness. They influence the proportion of total rainfall, runoff as well as the velocity of runoff water.

Vegetation cover is the most important factor in any reasonable erosion control program because it protects the soil from the direct impact of rain drop, stabilizes the soil, increases organic matter content of soil hence, improve structure reduces velocity of runoff and ultimately, reduce the volume of soil loss. Vegetation cover has the capacity to reduce paddling of surface water and help to maintain infiltration rate by slowing runoff. Crop roots produced in the soil and residues returned to the soil are capable of influencing soil structure stability, infiltration rate and permeability and forestall excessive soil erosion. The type of crop, its stage of growth and the management can combine or in isolation influences the amount of soil improvement and combat erosion. Some crops maintain good crop cover thereby reducing erosion, others keep the affected land bare for extended period of time and at the same time permit erosion perturbation, and canopy density and tillage method can also affect soil status. As efficient cover cropping is critical in soil protection process as it protects the soil from the direct impact of rainfall.

Several on farm activities, particularly tillage operations which constitutes a veritable component of a successful farming operations is usually a common feature in land area cultivated to cassava or any other crop in agricultural landscape. Obviously, the concept of tillage in land management operation occupies an important place in soil protection process. Although, the effects of tillage may be widespread on one hand, hence, its influence on soil erosion; but by incorporating crop residue below the soil surface or leaving it on the surface can potentially reduce the vulnerability of soil to the impact of rain drops or runoff. However, unguided tillage or prolonged tillage or other negative farming activities on a particular land area could adversely affect land stability and make it vulnerable to easy wash by runoff.

From the foregoing, it could be said that the soil textural characteristics and land cover type are the key elements that determine the level of soil loss in the area. The result of this research proved that soil characteristics and land use greatly influence erosion perturbation contrary to the hypothesis that, sediment lost is not influenced by land use cover in the area. Thus, supporting the assertion of UNEP in 1992 that the area is prone to erosion menace, hence the need to urgently design protection strategies.

4. Conclusion

The result of this study reveals that the dominant particle size fraction were those of sand. Sand lacks cohesion thus, making it susceptible to erosion perturbation. From the finding, it becomes evident that land use type and the ease of detachment and transportation of soil materials are the main consequence of soil degradation *vis a vis* the huge sediment yield in bare land areas. This is so because, considering the amount of sediment that cascades from the bare land surface down the slope which is an indication of the degree of exposure of this land surface coupled with the vulnerability status as revealed in the results.

Consequently, the severity of the impact usually manifest in areas where soil particles are transported and deposited as "false" soil. This type of soil can greatly undermine agricultural production including other land related projects since they do not support optimal crop growth nor enhance the articulation of sustainability driven projects which utilizes the advantages that are inherent in ideal land environment that is devoid of undue alteration that is often occasioned by anthropogenic activity. The danger of over grazing, forest destruction and other human related activities in the area cannot be over emphasized as they are responsible for the aggressive removal of soil materials which in a long run offsets the natural balance thus, affecting the overall productivity of the ecosystem if not checked. The study recommends a practical approach of soil management that will have to include the use of appropriate farming system, cropping system, the use of terracing or zero tillage method especially on a sloppy terrain as these would encourage continuous vegetal cover. These will ameliorate the effects of soil erosion and enhance soil structure or aggregate stability and ensure environmental sustainability.

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